

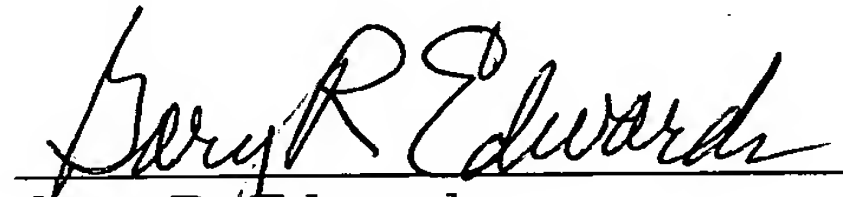
REMARKS

Entry of the amendments to the specification and claims, as amended by way of Annexes to the International Preliminary Examination Report for PCT/EP03/09085) before examination of the application in the U.S. National Phase is respectfully requested.

If there are any questions regarding this Preliminary Amendment or the application in general, a telephone call to the undersigned would be appreciated since this should expedite the prosecution of the application for all concerned.

If necessary to effect a timely response, this paper should be considered as a petition for an Extension of Time sufficient to effect a timely response, and please charge any deficiency in fees or credit any overpayments to Deposit Account No. 05-1323 (Docket # 056226.55708US).

Respectfully submitted,



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Attachment – Abstract of the Disclosure
355133v1

ABSTRACT OF THE DISCLOSURE

~~The present invention relates to~~ In a method of measuring stress/strain by ~~means of the detecting~~ Barkhausen noise, ~~and is characterized in that~~ an exciting/sensing device (1; 2,3; 2,7) is arranged at least adjacent to a magnetic or magnetizable element, and passing an increasing magnetizing current through (4; 5), ~~in that the exciting device, (1; 2) is acted upon by a rising magnetizing current, in that the~~ The start of the Barkhausen noise in the element, (4; 5) ~~is detected~~ as a function of the magnetizing current is detected by ~~means of the~~ sensing device, and the magnetizing current at that time represents (1; 3; 7), ~~the starting of the Barkhausen noise representing~~ a measurement of the stress/strain condition of the element. [[(4; 5).]]

METHOD OF MEASURING STRESS/STRAIN BY MEANS OF BARKHAUSEN NOISE

BACKGROUND AND SUMMARY OF THE INVENTION

[0001] This application claims the priority of German patent document 102 39 017.7, filed August 20, 2002 (PCT International Application No. PCT/EP2003/009085), the disclosure(s) of which is (are) expressly incorporated by reference herein.

[0002] The present invention relates to a method of measuring stress/strain by means of Barkhausen noise, such as may be. ~~The invention is~~ used, for example, ~~for measuring the~~ to measure stress/strain ~~[[of]]~~ in bolts or rivets at the wing or fuselage of an airplane, particularly during maintenance work.

[0003] For example, for tightening bolts, torque wrenches have been used, while simultaneously determining the internal stress in the bolt by means of ultrasonic ~~speed~~ measurements. However, this technique requires that the bolt ~~[[is]]~~ be coated or laminated with a piezoelectric, which makes ~~the bolt~~ it considerably more expensive.

[0004] In addition, it is known to use micromagnetic methods and sensors~~[[,]]~~ which ~~are based on the~~ measure Barkhausen noise, ~~for the detection~~

~~of to detect~~ material changes ~~as a result of~~ caused by treatment processes, based on the proposition ~~. In this case, the recognition is utilized~~ that the magnetic structure of the materials is influenced by the characteristics of the material. Crystallite limits and other inhomogeneities ~~[[,]]~~ (such as dislocations, foreign atoms and inclusions) hinder the movement of the so-called ~~Bloek~~ Bloch walls; and ~~[[. The]]~~ detachment of the walls from inhomogeneities results in ~~bounces~~ "bounces" in the magnetization, ~~[[the]]~~ or so-called "Barkhausen noise". ~~By means of a coil, these~~ These jolt-type movements of the Bloch walls can be recorded in the form of brief electric pulses, using a coil. The number, height and intensity of the pulses depends on the material and ~~[[the]]~~ its condition.

[0005] Such a method for the nondestructive ~~characterization~~ evaluation of ferromagnetic materials is known, for example, from German Patent Document DE 196 31 311 C2. The measuring principle is based on the fact that, when a ferromagnet is periodically reversed, the magnetic domain structure is continuously changed, and ~~. When the magnetization is changed,~~ boundaries between areas of the same magnetization (that is, Bloch walls) move through the material structure and interact with the microstructure of the material. This interaction is received as an electromagnetic signal - the so-called Barkhausen noise. ~~[[.]]~~

[0006] Such methods, which are based on an analysis of the Barkhausen noise, are generally used for quality control; ~~. They are used,~~ for example, for optimizing different treatment processes (grinding, heat treatment, etc.) of components. The components may, for example, be ground parts, camshafts,

crankshafts, bearings, gear wheels, injection valves and numerous other parts from automotive engineering and the aerospace field.

[0007] ~~It is an~~ One object of the invention is to provide a fast and simple method of measuring stress/strain, ~~which rapidly and at low equipment expenditures~~

[0008] Another object of the invention is to provide such a method which is capable of determining ~~particularly~~ stress/strain conditions ~~[[of]]~~ in fastening devices.

[0009] ~~According the invention, this object is achieved in that~~ These and other objects and advantages are achieved by the method according to the invention, in which an exciting/sensing device is arranged at least adjacent to one magnetic or magnetizable element ~~[[;]]~~ (preferably ~~at least~~ in a partial area around the magnetic or magnetizable element), so that it ~~[[;]]~~ ~~in that the exciting device~~ is acted upon by a rising magnetizing current. The sensing device thus detects ; ~~in that~~ the starting of the Barkhausen noise in the element (which is a measurement of the stress/strain condition of the element) ~~is detected~~ as a function of the magnetizing current. ~~by means of the sensing device, the starting of the Barkhausen noise being a measurement of the stress/strain condition of the element.~~ Expediently, the starting of the Barkhausen noise is determined by a comparative measurement ~~with respect~~ relative to reference values.

[0010] The invention has the advantage that the physical effect of the Barkhausen noise is effectively utilized. The stress/strain condition of a magnetic or magnetizable element (preferably ferromagnetic) ~~element~~ is determined in a contactless manner by a simple mounting of an exciting/sensing device. In this case, the element is magnetized by the magnetic field generated by the exciting device, and the sensing device detects the Barkhausen noise.

[0011] ~~It is particularly expedient to construct~~ In a preferred embodiment, the exciting/sensing device is constructed in one piece~~[[,]]~~ (preferably ~~by means of~~ a single coil), which acts simultaneously as an exciting device and a sensing device. ~~In this case, the~~ The sensing device detects the magnetizing current at which the Barkhausen noise occurs, the magnetizing current being proportional to the internal stress in the element. Such an arrangement has the advantage that the equipment expenditures are kept as low as possible.

[0012] ~~According to~~ In an alternative embodiment, the exciting device is again constructed as a coil, but ~~—However,~~ the sensing device for detecting the Barkhausen noise is an acoustic or interferometric detector, which is notable for its ~~—Such sensors are advantageously distinguished particularly by~~ small dimensions.

[0013] A pulsed magnetizing current is expediently used for excitation, ~~in which case,~~ and during the off-time of the pulses, the sensing device is set to receive the Barkhausen noise. This arrangement has the advantage that higher

magnetic fields can be generated without thermally overloading the exciting device.

[0014] According to ~~[[a]]~~ another preferred embodiment, ~~it is advantageous to arrange~~ an intermediate element of a non-magnetic or non-magnetizable material (e.g., a washer or the like) is arranged between the magnetic or magnetizable element (for example, a fastening device in the form of a bolt) and a structure, such ~~(for example, a component, which is [D])~~ to be connected therewith. ~~The magnetic or magnetizable element is, for example, a fastening device in the form of a bolt, and the intermediate element may be a washer or the like.~~ This embodiment has the advantage that it measures directly the stress existing in the fastening device as a result of the fastening ~~is measured directly~~. The washer is optional and preferably consists of a non-ferromagnetic material.

[0015] ~~According to~~ In an alternative embodiment, ~~it is expedient to first arrange~~ a magnetic or magnetizable element is first arranged between a non-magnetic or non-magnetizable fastening device and a structure to be connected therewith. Advantageously, stress/strain conditions of a non-magnetic fastening device can therefore also be determined ~~because~~ by measuring the mechanical stress ~~is measured which~~ that is transmitted by the fastening device to a preferably ferro-magnetic element (for example, a washer).

[0016] The method according to the invention is preferably used when measuring stress/strain conditions of fastening devices (such as screwed or

inserted bolts, rivets, etc.). The method can be used in multiple manners, for example, in the maintenance of airplanes, helicopters, motor vehicles, etc.

~~In the following, the invention will be described in detail by means of the attached drawings.~~

[0017] Other objects, advantages and novel features of the present invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] Figure 1 is a schematic representation of a preferred embodiment for implementing the method according to the invention;

[0019] Figure 2 is a view of representations of experimental measured values of the Barkhausen noise;

[0020] Figure 3 is a schematic representation of a measuring arrangement as an alternative to Figure 1; and

[0021] Figure 4 is a schematic representation of an alternative measuring arrangement by means of a riveted connection.

DETAILED DESCRIPTION OF THE DRAWINGS

[0022] Figure 1 shows a bolt 4 which is connected with a structure 6. As a rule, the bolt 4 is used for the fastening, fixing or holding of the structure which may comprise several components. The connection between the bolt 4 and the structure 6 may be screwed, riveted, inserted or the like. In the case of the screwed bolt illustrated in Figure 1, a washer 5 is as a rule arranged between the head 4a of the bolt and the structure 6.

[0023] For determining the stress/strain condition of the bolt 4, in a first step, the coil, which has the reference number 1 in Figure 1, is fitted over, onto or adjacent to the head 4a of the bolt. ~~However, the coil 1 can also be fitted onto the head 4a or be arranged adjacent to the bolt 4.~~ According to a preferred embodiment, the coil is used both for generating a magnetic field ~~as well as~~ and for detecting the Barkhausen noise, ~~which in the following will be~~ as described in greater detail hereinafter. However, instead of the ~~individual~~ single coil 1, separate components can also be used: ~~[[;]]~~ for example, a first coil, ~~which is used~~ for generating the magnetic field, ~~as well as~~ and a second coil which is used for detecting the Barkhausen noise. In the following discussion, reference will be made to the alternative embodiment, in which the exciting coil has the reference number 2 and the sensor coil has the reference number 3, in each case by placing the corresponding components in parentheses.

[0024] The coil 1 (or the exciting coil 2) is first used as a magnetizing coil and is excited by means of a magnetizing current for generating a magnetic field.

If the bolt 4 ~~consists~~ is made of a ferromagnetic material, the magnetization field has the effect that the ~~molecular~~ elementary magnets are aligned by the magnetic field of the coil 1 (or the exciting coil 2) through which the current flows. As known, the ~~flipping-over~~ reversal of the ~~molecular~~ elementary magnets is an erratic process (see Figure 2) which results in a change of the magnetic flux, whereby a tension change is induced in the coil 1 (or in the sensing coil 3). ~~In this case, the~~ The start of the ~~flipping-over~~ reversal or alignment of the ~~molecular~~ elementary magnets is a function of the magnetizing field intensity (or of the magnetizing current) ~~as well as of~~ and internal mechanical stress in the material. ~~In this case, a~~ (A tensile stress applied to the bolt 4 ~~acts against~~ opposes the alignment of the ~~molecular~~ elementary magnets, or causes the ~~molecular~~ elementary magnets to start to ~~flip-over~~ reverse once again, into their original alignment.) This ~~flipping-over~~ reversal of the individual ~~molecular~~ elementary magnets, in turn, generates a change of the magnetic flux, whereby currents (the so-called Barkhausen noise) are induced in the coil 1 (or in the sensing coil 3). Since the magnetic field intensity (or the magnetizing current) required ~~for the magnetizing of~~ to magnetize the bolt 4, ~~or the magnetizing current~~ is also a function of the internal mechanical stress, the stress/strain condition of the bolt 4 can be determined. In other words, a continuously rising magnetizing current generates a continuously rising magnetic field in the coil 1 (or the exciting coil 2), ~~in which case~~ and the magnetizing current present at the start of the Barkhausen noise is a measurement of the tensile stress applied to the bolt 4.

[0025] As a rule, a pulsed magnetizing current is used ~~for keeping to keep~~ the thermal loading of the coil 1 (or of the exciting coil 2) as low as possible. Simultaneously, the start of the Barkhausen noise is monitored as a function of the magnetizing current through the coil 1 (or through the sensor coil 3). The measurement takes place inductively, the coil 1 in each case being set during the off-time of the pulses of the magnetizing current to receive the Barkhausen noise. For ~~[[the]]~~ a precise determination of the stress/strain condition, comparative measurements, ~~are used as the reference which had been determined beforehand at the bolts (or rivets, etc.) made of the same material and of the same geometry,~~ are used as a reference. The stress/strain condition is therefore determined by comparative measurements with previously determined measured values, for example, electronically filed in a table.

[0026] In addition, it should be noted that, during the measurement of the stress/strain condition of, ~~[[a,]]~~ for example, a ferromagnetic bolt, a washer made of a non-magnetic or non-magnetizable material should be used which, in the following, analogous to Figure 1, has the reference number 5'.

[0027] ~~In addition, by means of the~~ The method according to the invention, can also be used to determine the stress/strain condition of a non-magnetic or non-magnetizable bolt ~~can also be determined which, analogous to the previous indicating method, in the following, will have the reference number 4'.~~ In this case, a washer 5 made of a magnetic or magnetizable material is used, so that the stress transmitted from the bolt 4' to the washer 5 is correspondingly

determined ~~by means of the above described measuring method~~ in the manner described above.

[0028] As an alternative, instead of ~~being determined inductively~~ inductive determination by means of a sensing coil 3, the Barkhausen noise can be detected by means of an acoustic or interferometric detector 7, ~~which is schematically~~ schematically illustrated in Figure 3. The principle on which the invention is based is unchanged, only the Barkhausen noise is determined in a different fashion. The detector 7 may, for example, be a microphone or a piezoelement, to mention only a few examples.

[0029] Figure 4 shows another alternative measuring arrangement on ~~[[the]]~~ an example of a riveted connection. In Figure 4, ~~[[the]]~~ a rivet 8 is connected with ~~has the reference number 8 and the structure equipped therewith, corresponding to the indicating method in Figure 1 or Figure 3, has the reference number 6; and an .~~ In addition, in Figure 4, the exciting coil 2 and the sensing coil 3 are illustrated separately as wire-wound coils around a core 9. The exciting coil 2 is again acted upon by a variable magnetization, and the sensing coil 3 detects induced stress by flipping over the domains. Instead of the sensing coil 3, an acoustic or interferometric detector 7 can also be used here for the detection of the Barkhausen noise.

[0030] The foregoing disclosure has been set forth merely to illustrate the invention and is not intended to be limiting. Since modifications of the disclosed embodiments incorporating the spirit and substance of the invention may occur

to persons skilled in the art, the invention should be construed to include everything within the scope of the appended claims and equivalents thereof.